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Introduction

The ability to accurately triage trauma patients can be problematic in the prehospital environment. Many prehospital triage scores have been developed to facilitate this process, perhaps demonstrating that a good deal of uncertainty remains in these methods.[1-18] The primary reason to perform prehospital scoring is to determine if the patient should be transported immediately to a trauma center (TC) and thus benefit from the TC's ability to rapidly provide lifesaving interventions (LSI), resulting in the survival of patients that would have otherwise died.[19-27]

The potential benefit of the TC is related to the concentration of experienced personnel and technology at one location that specializes in the care of seriously injured patients. Organized TC's have been shown to decrease preventable mortality in the intermediate group of patients that arrive seriously ill. Mortality in current mature TC's is approximately 3% of admissions and usually occurs in patients that have devastating injuries and a very low probability of survival, despite very aggressive diagnostic and intervention maneuvers.[27] Thus using mortality as the primary endpoint of a prehospital triage tool only identifies those small numbers of patients who received a LSI and died at the TC rather than those who received LSI and benefited from the intervention. Others have recommended utilizing an Injury Severity score (ISS) > 15 as an indicator of appropriate triage, however these data are not available until hospital discharge. This highlights the fact that while ISS is often appropriately used to retrospectively compare outcome between groups of patients, the data that are used to compile the ISS are not available until discharge from the hospital. Thus the ISS is not a tool that can be utilized for prehospital or even ED triage. More importantly, up to 25% of patients with low (1 - 9) ISS scores required the resources available at TC's.[28]

A more useful prehospital triage tool would identify those patients who actually required a lifesaving intervention.[29] This resource based triage endpoint would focus on those patients that were transported to a TC and received and benefited from LSIs.[9] Those that were transported to a TC and did not receive LSIs and survived comprise the group that perhaps could have been transported to a non-trauma center and done just as well. Many studies have demonstrated that Trauma Systems have not developed a sensitive and specific prehospital triage tool capable of identifying patients that would and would not benefit from evaluation at the TC. In an initial

attempt to develop a prehospital triage tool based only on prehospital data whose endpoint is resource based, we hypothesized that physiologic data immediately available upon scene arrival would prove predictive of the need for a LSI.

Body

For this study, a random connivance sample of trauma patients transported from the scene by the Life Flight System (LF) helicopter to Memorial Hermann Hospital, an urban Level I trauma center in Houston Texas, were eligible for the study. This study was approved by The Committee for the Protection of Human Subjects of the University of Texas Health Science Center at Houston. The Life Flight Helicopter service consists of three Eurocopter BK 117B's. An experienced pilot, flight medic and nurse comprise the helicopter flight crew. Trauma patients discharged home from the emergency department (25%) were not included in this data set. Patient inclusion criteria were as follows: (1) all trauma patients transported directly from the incident scene and (2) an injury necessitating admission to the hospital. All data were collected on a standardized data collection form and entered into a research database specifically designed for this study. A single research nurse performed all data entry. Patients were routinely monitored from the scene, during transport and into the Emergency Center with the Propaq 206 monitor. The physiologic data used in this study were manually recorded on the run sheet from the screen on the portable monitor. Vital signs, Glasgow Coma Score (GCS), capillary refill, age, gender, mechanism of injury and interventions were recorded on flight charts. The most abnormal physiologic data recorded during the flight were utilized for data analysis. Patients with injuries requiring LSIs were compared to those who did not require LSIs. Prehospital lifesaving interventions (P-LSI) were based upon procedures outlined in the Life Flight protocols (Table 2). Hospital based life saving interventions (H-LSIs) were determined based on review of all International Classification of Disease, Clinical Modification.

(ICD-9) procedure codes entered into the trauma registry from a 12 month sample of admitted trauma patients. These 306 procedures were then classified as LSIs (153 procedures in 13 major groups) or non-LSIs based upon a multidisciplinary panel of trauma experts (Table 3).

P-LSIs were timed and recorded by flight medical personnel, while final diagnosis, ICU, intermediate, floor or observation unit admission, H-LSIs, ISS and mortality were prospectively

recorded or calculated from the inpatient records by a single research nurse. By definition all LSIs must have occurred within 24 hours of the injury.

The predictive elements were used to correctly identify the patients that had an LSI and should be transported to the TC, thus defining sensitivity. Likewise, the predictive elements were used to correctly identify those patients not needing an LSI and thus not requiring TC care, thus defining specificity. Univariate associations between predictor variables and LSI were estimated using contingency table analyses (categorical variables), or t-tests or Wilcoxon rank-sum tests (continuous or near-continuous data) as appropriate. Multivariable tests of association were computed using multiple logistic regression analysis. Because the goal of the multivariable analyses was to construct probability estimates that can be used readily in the field, we used continuous variable cut points that are commonly in use in the clinical arena. A Glasgow motor function score of less than six was considered abnormal. A systolic blood pressure of less than 90 mmHg was considered hypotensive. Indicator variables for these conditions were created and included in multiple logistic regression models. Initial model evaluation was conducted using stepwise selection. Subsequently, best subsets regression was performed, and only variables that were statistically significant and contributed to the stability of the regression estimates were retained in the final model. Multivariable probabilities were computed by standard transformation of the logistic regression odds. Sensitivity and specificity of the final model were evaluated using receiver operating characteristic (ROC) analysis. All computations were performed using SAS version 8.02 running under Windows 2000 (SAS/STAT User's Guide. Cary, NC: SAS Institute, Inc). The null hypothesis was rejected at $p < 0.05$.

Reportable Outcomes

The demographics of the 216 patients included in the study are depicted in Table 1. Where appropriate, quartiles were established for descriptive and physiologic data. Age was not different between groups, nor did male gender predispose to an LSI. Likewise increasing patient age did not increase the requirement of an LSI. Longer transit time was not associated with LSIs. Not unexpectedly, death, increasing ISS and penetrating injury were associated with an LSI. The majority of patients did not require a LSI (63%), all those that died (6%) received a LSI, while 33% of survivors underwent an LSI. Patients were admitted equally to the Intensive

Care Unit (ICU) (46%) or the floor (51%). However, LSIs were performed on ICU (66%) patients more frequently than floor (8%) patients.

Lives saving interventions were subdivided into prehospital (P-LSIs) and hospital (H-LSIs). The majority of P-LSIs were intubations, performed on 35 patients, of which 34% ultimately died (Table 2). Other P-LSIs were rarely performed, and were associated with high mortality. Table 3 documents that H-LSIs were performed more frequently (31% of patients) and with a lower mortality (15%) than P-LSIs. The most frequently performed H-LSI was transfusion of PRBC with a mean transfusion during the first 24 hours of 7 ± 6 units and a mortality of 13%. Abdominal operations and chest tubes were performed frequently and with significant mortality.

The physiologic variables available at the injury scene were evaluated in Table 4. Univariate analysis demonstrated that an increasing pulse, delayed capillary refill, abnormal motor score, and SBP < 90 mmHg were associated with a LSI. Multivariate analysis demonstrated that an abnormal motor score (< 6) and a SBP < 90 mm Hg were independently associated with LSIs (Table 5). These data document that trauma patients with a systolic blood pressure < 90 mm Hg and motor score < 6 had a lifesaving intervention performed 95% of the time. When one or the other variable was present a LSI was performed 61-77% of the time. When neither was abnormal an LSI was still performed 21% of the time. Figure 1 shows an ROC curve for the final logistic regression model. Area under the curve is 74.4%, demonstrating good model discrimination.

The 33 (21%) patients that received a LSI but had a normal motor score and blood pressure were analyzed as a separate group. These patients did not reveal any physiologic variables that predicted a LSI, and none of the patients died. Penetrating injury was significantly increased in this group (24%) compared to entire study population (10%). Prehospital LSI (3 intubations and 1 needle decompression in 4 patients) were performed less frequently than in the larger study population (13% vs 19%). Hospital LSI's (3 intubations, 13 chest tubes, 10 operations and transfusion) were performed on 29 patients. Mean ISS was 14 ± 8 and the mean age in this group 38, was 5 years older then the study as a whole.

Discussion

Hospital based trauma scoring systems utilize data that is only available after patients have been thoroughly evaluated, operated upon or are ready for discharge. These hospital

scoring systems are primarily utilized for research, quality assurance programs and comparing different institutions and systems. The goals of a clinically useful prehospital triage rule should be somewhat different. A practical prehospital triage rule would be simple to remember, easy to acquire and most importantly predict those patients that will either require TC treatment or not.[14] A prehospital triage rule should assist the medical personnel working outside the sheltered environment of the hospital with decision making regarding optimal patient transport. In the civilian environment this usually revolves around the issue of transport to a trauma or non-trauma center. In the military arena this triage rule would determine when evacuation should occur, rather than location.

Trauma systems decrease mortality compared to non trauma systems.[19-27] They accomplish this by rapidly moving patients to centers where interested, experienced personnel can rapidly perform lifesaving interventions. However, one of the major problems with current prehospital scoring and triage rules are that they purposely over triage patients to the TC, i.e. they are not specific enough to reliably predict those patients not requiring TC care. Therefore many patients are transported to the TC that do not benefit from the TC level of intervention and expertise. Paradoxically, these patients “clog up” the TC system, not infrequently slowing required interventions on seriously injured patients. The American College of Surgeons Committee on Trauma states that over-triage rates of 30-50% (specificity) are required to ensure seriously injured patients are transported to the TC and not under-triaged (5-10% acceptable rate, sensitivity) to a location where life saving intervention might be delayed.[31] When both SBP and the motor score are normal, 21% of patients still required LSIs. This group of patients should not be triaged to a non-trauma center and further work is required to develop a system that will identify these at risk patients. Furthermore, determining what LSI’s are required may determine trauma-training requirements.

Adding mechanism and anatomic injury information to existing pre-hospital triage rules has been theorized to increase the sensitivity of the trauma triage algorithms. However, in the absence of physiologic abnormality these additions often greatly increase the over-triage rate, resulting in the transport of a large number of patients that do not benefit from the expertise located at the TC.[30] Likewise using the gestalt or judgment of pre-hospital personnel as a triage criteria has not been shown to be independently predictive of TC triage.[13] A new focus on serial physiologic parameters incorporating the technologic evolution of noninvasive monitors and

handheld personal computers may allow new pre-hospital triage rules to be developed, that are both sensitive, specific and useful for pre-hospital trauma providers.

The use of LSI as an endpoint for pre-hospital triage is not a new concept. Baxt[9] and Garner[29] have suggested that a resource based outcome or a LSI rather than mortality is the optimal endpoint of pre-hospital triage. Baxt et al combined Glasgow motor score, systolic hypotension and penetrating mechanism and demonstrated a sensitivity and specificity of 92%.[9] Garner et al recently evaluated 4 different systems and concluded that Glasgow motor score and systolic hypotension had the strongest association with severe injury, and suggested prospective data collection to evaluate their recommendation.[29] The work described herein builds upon their efforts. Future studies (currently ongoing) will describe the incorporation of electronic physiologic data recording suitable for continuous data analysis. These data may be used to derive an algorithm useful in the remote trauma triage decision assist devices currently being developed in the Land Warrior integrated uniform system.

The data presented document that those trauma patients with a systolic blood pressure < 90 mm Hg and motor score < 6 had a LSI performed 95% of the time. When one or the other variable was present a LSI was performed 61-77% of the time. When neither was abnormal an LSI was still performed 21% of the time. All patients that ultimately died demonstrated an abnormal motor score, hypotension or both. Those that were physiologically normal still required an LSI 21% of the time, yet all lived. This later group represents the patients that may initially appear physiologically normal yet still require a LSI. These then are the patients that could easily be under triaged to a non-trauma center and potentially have a LSI delayed, thus increasing morbidity and mortality. Luna et al documented a similar finding.[32] New methods of pre-hospital triage may be required in these patients, possibly in the arena of real time analysis of electronically captured continuous or near-continuous noninvasive physiologic data.[33,34] The lack of pre-hospital real time analysis of easily available physiologic data is not in keeping with current hospital based practice, where these data are monitored by the trauma team and the trends integrated and utilized by the trauma team leader at all major decision points.[35]

Figure 1 is a receiver operating characteristic (ROC) curve derived from a multiple logistic regression model. This is a two-variable model with indicator values for abnormal Glasgow motor score (<6) and abnormal SBP (<90 mmHg). Classification accuracy of the

model is considered to be good, with 74.4% of the graph area being under the curve (c statistic). The ROC curve (Fig 1) demonstrates that when sensitivity is high (85%), specificity is less than optimal (~30%). Identification of additional variables in future studies may improve model discrimination. As the current estimates stand, the high specificity is consistent with the ACS over triage plan, so as to not "miss" injured patients.

Conclusions

The strength of this study resides in two areas. First, all data were collected by one Life Flight System, transported by one of three helicopters that delivered trauma patients directly from the injury scene to one urban regional TC. All pre-hospital medical personnel underwent uniform training and practiced under the same treatment protocols. All physiologic data were recorded on the same type of electronic monitor. Second, the study population had a relatively high incidence of hypotension (14%) and altered motor score (24%). This led to LSIs being performed in 37% of transported patients, probably reflecting a selection bias in patients transported by helicopter. There are two principle weaknesses in this study. First are the small numbers of patients available for evaluation. This study was intended to be an initial effort, documenting that pre-hospital data collection was feasible and that LSI was a reasonable endpoint. Second was that the performance of an LSI and the requirement for an LSI is not necessarily the same. This distinction will be difficult to separate. The LF personnel are all highly trained and experienced personnel, with a rigorous flight review process of every patient and procedure. Furthermore, all patients that died received a LSI, while only 37% of those that lived received a LSI. This evaluation leads one to believe that LSIs were not done without appropriate clinical justification.

Future studies will expand on the described approach utilizing physiologic trends and to determine the minimum data set necessary that is predictive of the need for LSIs. The ultimate goal of this project is to place in the hands of the pre-hospital medical provider a decision assist device that will assist him/her in arriving at the critical treatment, triage and evacuation determinations in the less obvious patients. Additionally, utilizing these data will achieve a data driven approach for determining what sensors are required for the Land Warrior system, rather than arbitrary pre-selection.

With the increasing use of automated data analysis, the use of field expedient decision support systems should be provided to pre-hospital medical personnel.[36] New technology not available until recently allows near continuous acquisition of multiple noninvasive pre-hospital physiologic signs. Recording the physiologic data from large numbers of trauma patients will create the physiologic based database necessary for this effort. New approaches to physiologic data analysis will be required to provide trend analysis of noninvasive physiologic data for the on scene medics. Rapid and accurate communication from the pre-hospital environment to the hospital is frequently unreliable, thus emphasizing the need for moving physiologic data analysis systems into the pre-hospital arena. While these systems are utilized in a few ICU settings, no such clinical decision support tools have been developed for the civilian pre-hospital medical community, much less the more austere military environment.[36-39] Integration of these physiologic data will allow the development of software that may facilitate real time analysis and deployment of decision assist devices that are small, rugged, rapid and accurate to assist medics in their pre-hospital triage decisions.

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Appendices

Appendix A: Tables

Table 1: Patient Demographics and Univariate Analysis

Variable	All Patients n (%)	LSI n (%)	Odds Ratio*	95% CI**	p***
All patients	216 (100)	80 (37)			
Female	58 (27)	23 (40)	1.16	0.63 – 2.16	0.64
Male	158 (73)	57 (36)			
Blunt	195 (90)	66 (34)	0.26	0.10 – 0.67	0.005
Penetrating	21 (10)	14 (67)			
Age					
Mean 33 ± 17					
Quartiles					
2 – 18	45 (21)	17 (38)	1.01	1.00 – 1.02	0.90
19 – 30	62 (29)	21 (34)			(0.62)
31 – 44	54 (25)	20 (37)			
45 – 83	54 (25)	22 (41)			
ISS					
Mean 12.2 ± 9.2					
Quartiles					
0 – 4	54 (25)	3 (6)	1.17	1.12 – 1.23	0.0001
5 – 8	24 (11)	5 (21)			(0.001)
9 – 12	74 (34)	28 (38)			
13 – 34	64 (30)	44 (69)			
Transit Time					
Mean 15 ± 7					
Quartiles					
6 – 10	54 (25)	23 (43)	0.96	0.92 – 1.01	0.15
11 – 12	40 (18)	11 (28)			(0.09)
13 – 17	62 (29)	28 (45)			
18 – 47	60 (28)	18 (30)			
Admition Status					
Floor	107 (50)	9 (8)	21.3	9.7 – 46.8	0.0001
ICU	102 (48)	67 (66)			(0.0001)
Morgue	4 (2)	4 (100)			

Length of Stay							
ICU							
Mean 1.4 ± 4.1							
0	142	(68.3)	24	(16.9)	15.3	7.52 – 31.3	0.0001
1 – 38	66	(31.7)	50	(75.8)			
Floor							
Mean 5.4 ± 6.8							
Quartiles							
0 – 1	14	(6.7)	12	(85.7)	1.02	0.98 – 1.06	0.0001
2 – 3	72	(34.6)	13	(18.1)			(0.33)
4 – 8	67	(32.2)	30	(44.8)			
9 – 63	55	(26.4)	19	(34.6)			
Total							
Mean 6.8 ± 9.2							
Quartiles							
1 – 2	48	(23.1)	9	(18.8)	1.06	1.01 – 1.11	0.0001
3 – 5	52	(25.0)	13	(25.0)			(0.02)
6 – 9	51	(24.5)	22	(43.1)			
10 – 101	57	(27.4)	30	(52.6)			
Alive	203	(97)	67	(33)	0.02	0.01 – 0.31	0.0001
Dead	13	(6)	13	(100)			

*For dichotomous variables, the odds ratio represents a test against a reference category whose referent odds ratio is equal to 1. For continuous data, the odds ratio refers to the increase in odds associated with a one-unit increase in the variable value. Although continuous data are presented in quartiles, the odds ratios are against the continuous variable.

** 95% CI = 95% confidence interval. This reflects the units against which its companion odds ratio is computed. Confidence intervals are test-based.

*** p = probability of Type I statistical error (common p value). Values without parentheses are Pearson Chi-square probabilities. Probability values in parentheses are univariate logistic regression likelihood ratio p values.

ICU, Intensive Care Unit;

Table 2: Prehospital LSI's and Associated Mortality

	P-LSI n (# of pts)	Mortality # of pts (%)
Total interventions	43 (37)	12 (32%)
Intubations	35 (35)	12 (34%)
Needle Thoracentesis	3 (3)	0 (0%)
Cricothyroidotomy	2 (2)	1 (50%)
Pericardiocentesis	2 (2)	1 (50%)
CPR	1 (1)	1 (100%)

Table 3: Hospital LSI within 24 hours of Admission and Overall Mortality

	H-LSI , N (# of pts)	Mortality # of pts (%)
Total interventions	152 (68)	10 (15%)
Intubation	7 (7)	0
Chest Tube	26 (26)	3 (12%)
OR Abdomen	49 (20)	5 (25%)
OR Head	9 (6)	3 (50%)
OR Chest	8 (4)	1 (25%)
OR Neck	5 (4)	0
OR Face	1	0
OR Spine	1	0
OR Extremities	1	0
PRBC transfusion (units)	279 (39)	5 (13%)
Arteriogram	3 (3)	1 (33%)
Defibrillation	2	1 (50%)
CPR	1	0

Table 4: Pre-Hospital Physiology Characteristics with Univariate Analysis

Variable	Patients n (%)	No. With LSI (%)	Odds Ratio*	95% CI**	p***
All patients	216 (100)	80 (37.0)			
Pulse					
Mean 102 + 23 (beats/minute)					
Quartiles					
48 – 83	50 (23)	15 (30)	1.02	1.01 – 1.03	0.02
84 – 99	52 (24)	17 (33)			(0.01)
100 – 115	58 (27)	17 (29)			
116 – 186	56 (26)	31 (55)			
Capillary Refill					
Delayed (> 2 sec)	19 (9)	17 (90)	17.43	3.90 – 77.88	0.0001
Normal (< 2 sec)	183 (91)	60 (33)			
Motor Score					
Abnormal (< 6)	51 (24)	37 (73)	7.50	3.70 – 15.20	0.0001
Normal (= 6)	165 (76)	43 (26)			
Systolic Blood Pressure					
Systolic < 90 mm Hg	31 (14)	27 (87)	16.81	5.61 – 50.37	0.0001
Systolic ≥ 90 mm Hg	185 (86)	53 (29)			
Respiratory Rate (breaths/minute)					
Intubated	19 (9)				
Non-intubated mean 22 + 9					
Quartiles					
6 - 18	28 (13)	13 (46)	0.98	0.94 – 1.03	0.12
19 - 20	28 (13)	8 (29)			(0.40)
21 - 24	76 (35)	18 (24)			
24 - 100	65 (30)	24 (37)			

Table 5: Probability of Requirement for LSI

N	Motor Score	SBP	Probability of LSI*	Mortality (%)
151	6	≥ 90 mmHg	21	0
34	<6	≥ 90 mmHg	61	3 (9)
14	6	< 90 mmHg	77	1 (7)
17	<6	< 90 mmHg	95	9 (53)

*Multiple logistic regression probability estimates

Appendix B: Figures

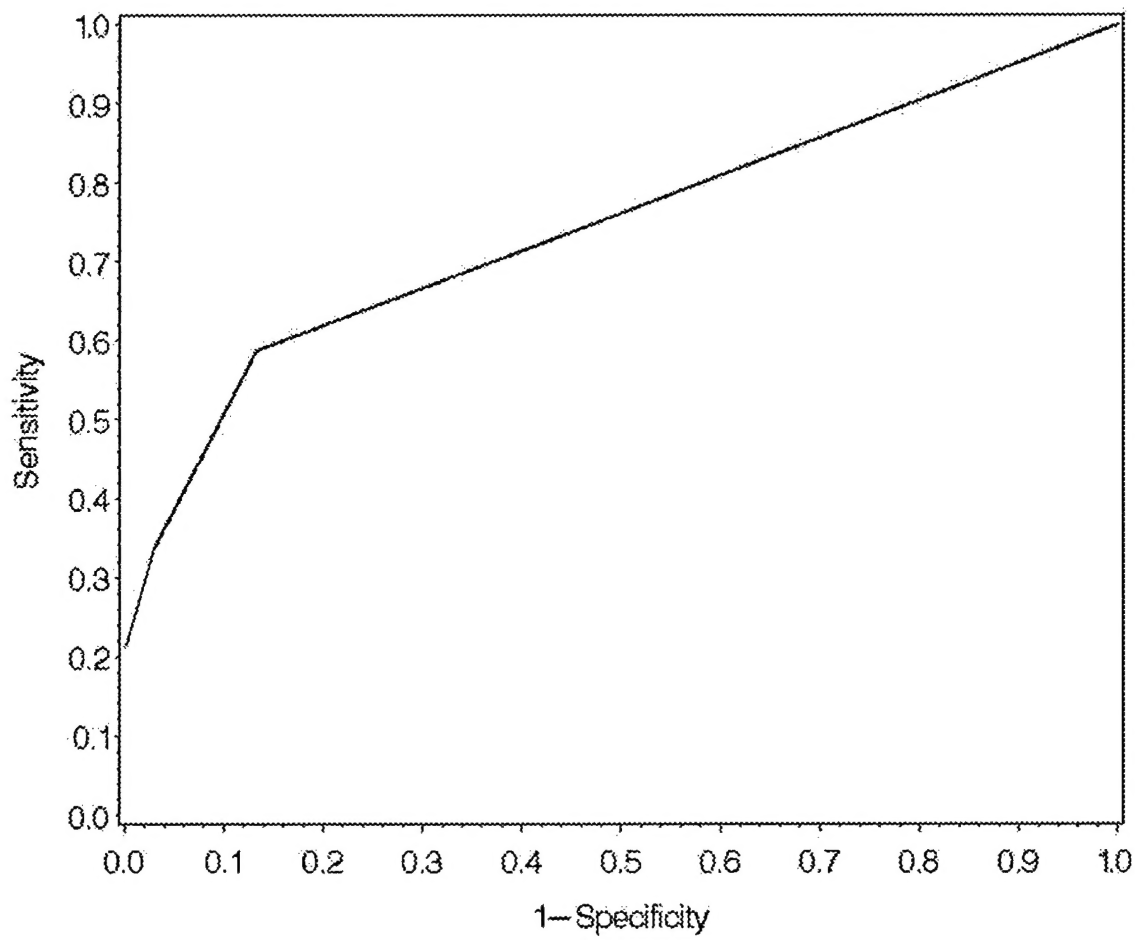

Figure 1: Receiver operating characteristic curve

Receiver operating characteristic (ROC) curve describing screening characteristics of logistic regression model. 1-specificity is equal to the false positive rate as given by false positives divided by nonevents. At any given point along the line, the tradeoff between sensitivity and specificity can be observed. Area under the curve is 74.4%.